In re Appln. of WUNNING et al.
Application No.

REMARKS

Applicants have cancelled claims 1-14 and added new claims 15-28. In addition, applicants are submitting herewith a replacement specification which addresses various usage issues resulting from the translation from the original German language application. No new matter has been introduced by way of the replacement specification.

The application is considered in good and proper form for allowance, and the Examiner is respectfully requested to pass this application to issue. If, in the opinion of the Examiner, a telephone conference would expedite the prosecution of the subject application, the Examiner is invited to call the undersigned attorney.

Respectfully submitted,

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COMBUSTION CHAMBER WITH FLAMELESS OXIDATION

FIELD OF THE INVENTION

[0001] The invention ~~concerns~~ relates to a combustion chamber for a gas turbine and a gas turbine equipped with such a combustion chamber.

BACKGROUND OF THE INVENTION

[0002] Gas turbines are used to convert heat energy to mechanical energy~~, which is~~ that can be delivered to a shaft (e.g., in a power plant, ship power plant, helicopter) or delivered as thrust (aircraft). All gas turbines have combustion chambers in which a fuel is burned with excess air. ~~A~~ During combustion, a stable flame is ~~then~~ formed in the combustion chamber. The gas flow, which has a very high velocity at the compressor outlet, is generally initially slowed for stabilization. Appropriate ~~means~~ systems are provided to form stable flames. For example, small eddies are generated in the combustion chamber for flame stabilization. Combustion occurs with excess air so as not to cause thermal overload of the combustion chamber and turbine.

[0003] Flameless oxidation of a fuel in a corresponding reaction space is known from EP 0463218 B1. Flameless oxidation is achieved at high combustion temperatures when the fuel is introduced to a ~~hot exhaust- and oxygen-containing~~ gas stream containing hot exhaust and oxygen.

[0004] Combustion chambers of gas turbines ~~must satisfy~~have several design requirements. ~~Some of them are the least possible~~These include minimizing pressure loss, ~~as complete as possible~~maximizing combustion, ~~falling~~ producing (just) ~~short of~~under the maximum exhaust temperatures (to spare the turbine), and limited generation of NO_x.

OBJECTS AND BRIEF SUMMARY OF THE INVENTION

[0005] ~~The task of devising~~In view of the foregoing, an object of the present invention is providing a combustion chamber that has low NO_x generation and is suitable for use in gas turbines~~ is derived from this~~.

~~[0006]This task is solved with the combustion chamber according to Claim 1:~~

~~**[0007]**~~**[0006]** The combustion chamber according to the invention is ~~set up~~configured for flameless oxidation. This is achieved by aligning the inlet and outlet so that a large-volume recirculation flow is formed in ~~its~~ the internal space of the combustion chamber.~~, with which~~ As a result of this, larger amounts of hot exhaust gases are mixed with the supplied fresh air. ~~The~~ Preferably, the ratios are preferably such that at least twice as much exhaust stream is mixed with the fresh air stream. Consequently, a situation can be achieved in which the mixture of fresh air and exhaust has a ~~mixing~~ temperature ~~that lies~~ above the ignition temperature of the fuel. The flameless oxidation that develops does not rely on formation of

a stable flame. ~~Relatively~~ Therefore, relatively high gas velocities can ~~therefore~~ be used~~, in which~~ and the oxidation of the fuel extends over a larger zone between the inlet and outlet.

~~[0008]~~[0007] The large-volume recirculation flow can also be configured to be relatively low loss~~, so that the~~ with the combustion chamber ~~has~~ having low flow resistance and therefore ~~causes~~ causing only limited pressure losses. Pressure losses ~~that lie in the range~~ of around less than 3% of the combustion chamber pressure are attainable. The fresh air is compressed and preferably fed to the combustion chamber as an air jet ~~free of~~without rotation. Ordered flow is produced.

~~[0009]~~[0008] The new combustion chamber permits high power densities (for example 100 MW/m^3). Flame collapse and blowback are, in principle, impossible. NO_x concentrations of less than 10 ppm are achieved.

~~[0010]~~[0009] To form flameless oxidation ~~with simultaneous achievement of a~~while simultaneously achieving a combustion chamber with low flow resistance ~~of the combustion chamber~~ and a compact design, the fuel is introduced to the combustion chamber in the same direction as the fresh air. ~~Because of this~~As a result, local eddies, which otherwise might contribute to an increase in pressure loss, are largely reduced.

~~[0011]~~[0010] The combustion chamber is preferably laid out with an internal recirculation of 2 to 5. This means that ~~exhaust gas~~fresh air is mixed in with two to five times ~~the mass flow of fresh air is mixed in with it~~as much exhaust gas.

~~[0012]~~[0011] The air and fuel are ~~then~~ preferably introduced coaxially in adjacent jets or in jets otherwise arranged next ~~to each other~~ and essentially parallel to each other in the combustion chamber. ~~Feed~~ The feed to the combustion chamber preferably occurs from the end wall ~~at the region~~in the area adjacent to the outer wall of the combustion chamber, i.e., in a ~~zone of the end wall lying~~ radially outward lying area of the end wall. ~~Because of this~~As a result, fresh air and fuel are initially introduced into the combustion chamber in ~~an essentially wall-parallel flow~~flow essentially parallel to the wall. The outlet of the combustion chamber is preferably oriented in the same ~~direction~~ or the opposite direction~~,~~ ~~its~~ with the outer boundary of the outlet being closer to the center axis of the combustion chamber than the air nozzles ~~for inlet~~at the inlet into the combustion chamber. A recirculation stream of larger volume can be achieved with this expedient. ~~It~~ The recirculation stream is guided along the wall from the inlet to the outlet of the combustion chamber, and then flows back from the outlet to the inlet, preferably on the center axis of the combustion chamber.

~~[0013]~~[0012] The inlet of the combustion chamber is preferably formed by several air inlet nozzles that ~~guide the~~act as fresh air jets guiding fresh air into the internal space ~~as fresh air jets~~. The air nozzles are also preferably formed so that the emerging air jet exerts an injector effect for return flow of exhaust gases. This can be achieved ~~or supported~~ by a conical section protruding above the end wall of the combustion chamber.

~~[0014]~~[0013] The combustion chamber can be part of individual combustion chambers arranged in ~~annular fashion in a set~~relation, which are also referred to as tubular combustion chambers. As an alternative, the combustion chamber can be laid out as an annular combustion chamber. In stationary installations alternative combustion chamber shapes are also possible.

~~[0015]~~[0014] The combustion chamber is preferably designed so that it has only a single circulation center (turbulence center). In the tubular combustion chamber this turbulence center is a line or surface arranged coaxial to the ~~combustion chamber~~ longitudinal axis of the combustion chamber. The circulation stream is a toroidal stream that encompasses the entire internal space of the combustion chamber. In the annular combustion chamber, in which the air nozzles belonging to the inlet are arranged, ~~for example, on an outer rim in the end wall,~~ the turbulence center ~~is~~ can also formed on an outer rim in the end wall by a circular line aligned coaxial to the longitudinal axis of the combustion chamber. This circular line is preferably roughly parallel to the line along which the air nozzles are arranged.

~~[0016]~~[0015] The combustion chamber is preferably provided with a preheating device ~~with which it can be brought at the beginning of operation~~for bringing the combustion chamber to a temperature suitable for flameless oxidation at the start of operation. The preheating device is formed, for example, by temporarily operated burners that can form a flame by means of electric heating or other heat sources.

~~[0017]~~[0016] The combustion chamber can be coated on its inside wall with a catalytically active material. In addition, a guide element with a catalytic surface can be arranged in the combustion chamber. A catalyst can also be arranged at the outlet of the combustion chamber.

~~[0018]Other advantageous details of variants of the invention are apparent from the drawing, description or dependent claims.~~

~~[0019]Embodiments of the invention are explained in the drawing. In the drawing:~~

~~[0020]Figure 1 shows a gas turbine in a schematic view,~~

~~[0021]Figure 2 shows the combustion chambers of the gas turbine according to Figure 1 in a front view,~~

~~[0022]Figure 3 shows an individual combustion chamber in a schematic, longitudinal view,~~

~~[0023]Figure 4 shows the combustion chamber according to Figure 3 in a front view,~~

~~[0024]Figure 5 shows a modified variant of the combustion chamber in a longitudinal view,~~

~~[0025]Figure 6 shows another modified variant of the combustion chamber in a longitudinal view,~~

~~[0026]Figure 7 shows a combustion chamber designed as an annular combustion chamber in a front view,~~

~~[0027]Figure 8 shows a combustion chamber according to Figure 7 in a longitudinal section,~~

~~[0028]Figure 9 shows a combustion chamber with reverse flow in a longitudinal view and~~
~~[0029]Figure 10 shows the combustion chamber according to Figure 9 in a front view.~~

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Fig. 1 is a schematic side view of a gas turbine according to the invention.

[0018] Fig. 2 is a front view of the combustion chambers of the gas turbine of Fig. 1.

[0019] Fig. 3 is a schematic longitudinal section view of an individual combustion chamber.

[0020] Fig. 4 is a front view of the combustion chamber of Fig. 3.

[0021] Fig. 5 is a longitudinal section view of an alternative embodiment of a combustion chamber according to the present invention.

[0022] Fig. 6 is a longitudinal section view of another alternative embodiment of a combustion chamber according to the present invention.

[0023] Fig. 7 is a front view of an alternative embodiment of a combustion chamber according to the invention in which the combustion chamber is configured as an annular combustion chamber.

[0024] Fig. 8 is a longitudinal section view of the combustion chamber of Fig. 7.

[0025] Fig. 9 is a longitudinal section view of an alternative embodiment of a combustion chamber according to the invention having reverse flow.

[0026] Fig. 10 is a front view of the combustion chamber of Fig. 9.

DETAILED DESCRIPTION OF THE INVENTION

~~**[0030]**~~**[0027]** A gas turbine 1 having a compressor 2, a turbine 3, which is connected to the compressor 2 via a shaft 4, and at least one combustion chamber 5, is shown in Figure 1. Each combustion chamber has an inlet 6, which is fed compressed air from compressor 2, and an outlet 7, which supplies the gas stream generated in combustion chamber 5 to turbine 3.

~~**[0031]**~~**[0028]** ~~The~~ As shown in Fig. 2, the combustion chambers 5~~, as shown in Figure 2,~~ can be roughly can-type burners which together form a combustion chamber set. A single such combustion chamber 5 is shown in Figure 3. The combustion chamber has an internal space 9 enclosed by a wall 8, which is essentially cylindrical. On the inlet side, an end wall 11, which can be ~~designed~~ flat, is part of the wall 8. On the opposite side, an end wall 12 is formed in which an opening 14 with radius B that defines the outlet 7 is arranged. A series of air nozzles 15 ~~which~~that, as shown in Figure 4, are arranged in a circle~~,~~ serves as the inlet 6. The air nozzles 15 are arranged in the vicinity of the wall 8 at a radius A, greater than the radius B of opening 14, from the imaginary center axis 16 of the combustion chamber 5. In a practically tested ~~variant~~embodiment, the diameter D of the nozzle opening of the air nozzles 15 is roughly 1/50th the length 1 of combustion chamber 5 measured along center

axis 16. The diameter of the combustion chamber is about half its length. The figures are not to scale.

~~[0032]~~[0029] A guide tube 17 can be arranged in the internal space 9 concentric to the center axis 16. The guide tube 17 is shorter than the length of the internal space 9. This diameter corresponds to roughly the diameter of the opening 14. ~~It has a spacing~~The guide tube is spaced from the end walls 11 and 12 a distance that is somewhat less than its radius. ~~Means of~~An arrangement for fastening the guide tube 17~~, for example bars,~~ to the wall 8 or end walls 11, 12 (e.g. bars) are not shown.

~~[0033]~~[0030] The air nozzles 15, as shown in Figure 3, extend into the internal space 9. For example, ~~they~~ the air nozzles have a roughly truncated conical contour. ~~They~~ The air nozzles are designed so that they produce a straight air jet that causes an injector effect. A fuel feed device 18 is provided to supply fuel. This is formed, for example, by fuel nozzles 19 that are fed by a central line 21. The fuel nozzles 19 can discharge right in front of an air nozzle 15. One fuel nozzle 19 can then be assigned to each air nozzle 15. It is also possible to assign fuel nozzles 19 to only some of the air nozzles 15. In addition, the fuel nozzles 19 alternatively can be arranged between air nozzles 15, as shown in Figure 4~~ as an alternative~~. The number of fuel nozzles 19 can match or differ from the number of air nozzles 15~~ or differ from it~~. The fuel nozzles 19 and the air nozzles 15 have the same outflow direction, i.e., the air and fuel are introduced ~~to~~ into the internal space 9 in the same direction.

~~[0034]~~[0031] The combustion chamber 5 also has a preheating device 22 for startup. In the ~~present~~ illustrated embodiment, ~~it~~ the preheating device is formed by a spiral-wound filament that can be heated electrically and is accommodated on the inside of wall 8. As an alternative, a burner, an arc generation device or another controllable heat source can be provided.

~~[0035]~~[0032] The combustion chamber 5 thus described operates as follows:

~~[0036]~~[0033] During operation of the gas turbine 1, the combustion chamber 5 receives compressed fresh air preheated by compression at its inlet 6. ~~The~~ For example, the pressure can be in the range from 10 bar to 20 bar~~, for example~~. The air is divided among the individual air nozzles 15 and therefore enters the internal space 9 in the form of jets roughly parallel to the cylindrical wall 8. This is shown by arrows 24, 25 in Fig. 3. The temperature in the internal space 9 is increased by the spiral-wound filaments 23 so that the introduced fuel is ignited. ~~This~~ The fuel is fed ~~via~~ fuel nozzles 19~~,~~ along with the fresh air stream, into the internal space 9 in the direction of arrows 24, 25. The fuel now reacts in this internal space on its way from the air nozzles 15 to the end wall 12. The annular channel formed between the outside of the guide tube 17 and the inside of the wall 8 therefore forms a reaction channel 26 that is traversed by the fresh air and fuel in the direction of arrows 27, 28.

~~[0037]~~[0034] The end of the reaction channel 26 is covered by end wall 12 so that the flow, which is indicated by arrows 29, 31 is reversed. Only a relatively smaller ~~part~~ portion of the formed reaction products flows via the outlet 7 through the turbine 5 as hot gas, as shown by arrows 32, 33. The relatively larger ~~part~~ portion recirculates through the guide tube 17 back to the end wall 11, therefore establishing a recirculation channel 34. The exhaust flowing back in the recirculation channel 34 is at the combustion chamber outlet temperature, for example 1300°C. The mass flow rate is two to five times the feed flow rate of the air through inlet 6.

~~[0038]~~[0035] The back-flowing gases are deflected radially on the end wall 11 and drawn into the reaction channel 26 by the inflowing fresh air with an injector effect. The hot exhaust mixes with the inflowing fresh air. The mixing temperature lies above the ignition temperature of the supplied fuel, for example above 720°C. The fuel fed with the fresh air therefore oxidizes completely, roughly along the length of the guide tube 17 within the reaction channel 26, without forming flame phenomena. No local temperature peaks develop within the gas volume.

~~[0039]~~[0036] After heating of the combustion chamber 8 and assumption of the described stable flameless operation, the preheating device 22 can be switched off. The flameless oxidation can be maintained in full and partial load operation as long as it is ensured that the combustion chamber 8 is overall kept ~~overall~~ at a temperature above the ignition temperature of the fuel, and as long as the illustrated flow pattern ~~shown~~ is maintained. The guide tube 17 here forms the areal turbulence center of the forming large-volume recirculation stream that has a tire-like or toroidal shape. The turbulence center is therefore stably localized ~~stably~~ and is coaxial to the center axis 14.

~~[0040]~~[0037] In an alternative embodiment of the combustion chamber 5 shown in Figure 5, the circulation flow is achieved merely by arranging the air nozzles 15 on the rim ~~apparent from Figure 4, formation~~(such as shown in Fig. 4) and ~~arrangement~~ arranging of the openings 14, and optionally by shaping of wall 8. The recirculation channel 34 and reaction channel 26 ~~here~~ in this case are not separated from each other by fixtures, but are determined by the forming flow. The turbulence center of the recirculation flow is indicated with a dashed line in Figure 5 at 35. It lies concentric to the center axis 16.

~~[0041]~~[0038] In a further ~~developed~~ embodiment, a high temperature catalyst is arranged in outlet 7. This serves for reaction acceleration, especially in the lower temperature ranges.

~~[0042]~~[0039] ~~A modified~~Another embodiment of the combustion chamber 5 is shown in Figures 7 and 8. This embodiment is designed as an annular combustion chamber. Where reference numbers used thus far are employed, the previous description applies accordingly. The following explanations serve as a supplement.

~~[0043]~~[0040] The combustion chamber 5 is an annular internal space 9 arranged concentric to the longitudinal center axis 16 and enclosed by the wall 8 both toward the center axis 16

and also outward. As shown in Figure 8, ~~this~~ the wall 8 can transition into the end walls 11, 12 with a curvature that is favorable from the standpoint of flow. Air nozzles 15 that lie on a circle concentric to the center axis 16 are arranged in the end wall 11 (Figure 7). The flow direction established by air nozzles 15 is essentially parallel to the center axis 16. The ~~End~~ end wall 12 can be provided with an annular slit-opening 14 or instead with a series of individual openings 14 arranged on a rim. The outer rim, i.e., the limitation 36 lying farthest outward radially, is arranged far enough inward radially that the air jet emerging from air nozzle 15 strikes the end wall 12 radially farther out. In other words, as in the previous embodiments, the imaginary linear extension 37 of the air nozzle 15 intersects the end wall 12 outboard of the opening 14. Accordingly, the flow emerging from the air nozzle 15 is diverted by 180° before the outlet 7 and for the most part flows back to the end wall 11, where it is diverted again by 180°. A large circulating flow is formed that runs along the entire length of the wall 8 of the combustion chamber 5. The turbulence center 35 is arranged concentric to the center axis 16. It passes through the internal space 9 roughly in the center. As shown with the dashed line, it can be established by a guide device 17' or merely by the shape of wall 8. As in the previous embodiments, flameless oxidation occurs, with a complete reaction between the fuel and the supplied fresh air~~,~~ on the way from the air nozzle to the end wall 12~~,~~ so that only waste gases are recirculated.

~~[0044]~~[0041] Another embodiment of the combustion chamber 5 according to the invention is ~~apparent from~~shown in Figures 9 and 10. The comments made relative to the combustion chambers according to Figures 3 to 5 apply accordingly. The following applies in addition:

~~[0045]~~[0042] The combustion chamber 5 according to Figure 9 operates with reverse flow. Whereas in the preceding combustion chambers, the inlet 6 and the ~~inlet [sic; outlet]~~ outlet 7 are arranged on opposite ends 11, 12 of combustion chamber 5, the inlet 6 and outlet 7 in combustion chamber 5 ~~according to~~of Figure 9 are arranged on the same end 11 of combustion chamber 5. This design is suitable for turbines of ~~smaller~~ relatively less power. It is typically applicable to turbines with radial compressors. The air nozzles 15 are arranged on a circle that encloses the opening 14 provided in end wall 11. The air nozzles 15 and the opening 14 are arranged concentric to the center axis 16. The circulating flow that forms (arrows in Figure 9) again has an annular circulation center 35 positioned concentric to the center axis 16. The circulation flow has a mass flow rate that exceeds the mass flow rate of the supplied fresh air by a factor of two to five.

~~[0046]~~[0043] In comparison with the embodiments just described, the advantage of ~~this~~ the Fig. 9 and 10 embodiment of the combustion chamber 5 is that almost the entire internal space 9 is utilized as a reaction space. Both the path from the air nozzle to the end wall 12 and the path from the end wall 12 to the outlet 14 can be used for reaction of the fuel. ~~A~~ As a result, a very compact design is ~~therefore~~ possible.

~~[0047]~~[0044] If necessary, the circulation center 35 can be fixed or stabilized by a guide tube 17. In addition, the end wall 12~~, as~~ (shown with a dashed line in Figure 9)~~,~~ can be curved as a torus, i.e., designed as a channel running around the center axis 16.

~~[0048]~~[0045] A combustion chamber 5 for a gas turbine is ~~set up~~adapted for flameless oxidation of fuels. ~~For this purpose it~~ To this end, the combustion chamber has an internal space 9 in which a larger recirculation flow is established. This recirculation flow feeds the introduced air to a hot exhaust stream whose flow rate exceeds that of the fresh air stream. The fresh air and the fuel are fed to the combustion chamber in the same direction, roughly parallel to the wall.

Claims:

1. Combustion chamber (5) for a gas turbine (1)

with an internal space (9) enclosed by a wall (8,11,12), which serves as a reaction space,

with an inlet (6,15), which leads into internal space (9) and is supplied with fresh air,

with at least one outlet (7,14), which emerges from the internal space (9) and serves to discharge hot exhaust gases,

in which the inlet (6,15) and the outlet (7,14) are aligned and the internal space (9) is designed so that a large circulating flow is formed in internal space (9) to maintain a flameless oxidation process

with a fuel feed device (18), set up to guide fuel into internal space (9) in a stipulated direction (24), with the fuel feed device and inlet (6,15) being oriented essentially the same.

2. Combustion chamber according to Claim 1, characterized by the fact that the cross sections of the inlet (6,15) and the outlet (7,14) and the geometry of the internal space (9) of the combustion chamber (5) are adjusted to each other so that the mass flow rate of the gas stream circulating in the internal space is larger than twice the mass flow rate of the stream introduced into inlet (6,15).

3. Combustion chamber according to Claim 1, characterized by the fact that the cross sections of the inlet (6,15) and the outlet (7,14) and the geometry of the internal space (9) of the combustion chamber (5) are adjusted to each other so that the flow rate of the gas stream circulating in the internal space is smaller than five times the flow rate of the stream introduced into inlet (6,15).

4. Combustion chamber according to Claim 1, characterized by the fact that the inlet (6,15) includes several air nozzles (15) arranged next to each other in a row.

5. Combustion chamber according to Claim 4, characterized by the fact that each air nozzle (15) has a section extending beyond wall (11).

6. Combustion chamber according to Claim 4, characterized by the fact that the air nozzles (15) have a corresponding orientation.

7. Combustion chamber according to Claim 1, characterized by the fact that the combustion chamber (5) is designed cylindrical and that the air nozzles (15) are arranged on a circle that is arranged concentric to combustion chamber (5).

8. Combustion chamber according to Claim 1, characterized by the fact that the combustion chamber (5) is designed as a circular ring.

9. Combustion chamber according to Claim 1, characterized by the fact that the inlet (6,15) and the outlet (7,14) are arranged, and the geometry of the internal space (9) is established, so that the forming circulation flow encompasses the entire internal space (9).

10. Combustion chamber according to Claim 1, characterized by the fact that the recirculation flow has only a single turbulence center (35).

11. Combustion chamber according to Claim 10, characterized by the fact that the turbulence center (35) lies on a curved line or a surface.

12. Combustion chamber according to Claim 1, characterized by the fact that the combustion chamber (5) has a preheating device (22).

13. Combustion chamber according to Claim 1, characterized by the fact that a guide device (17) is arranged in internal space (9) that divides the internal space (9) into a mixing and reaction channel (26) and a backflow channel (34).

14. Gas turbine (1)

with a compressor (2), a turbine (3) and with at least one combustion chamber (5) for flameless oxidation of fuel, enclosing an internal volume (9) and which has an inlet (6,15), which establishes an air inlet direction (24,25), that is connected to compressor (2), an outlet (7,14) that is connected to turbine (3), and a fuel feed device (18), which establishes a fuel introduction direction (24,25),

characterized by the fact that

the fuel introduction direction (24,25) and the air inlet direction (24,25) essentially agree.

~~Summary:~~ABSTRACT

A combustion chamber (5) for a gas turbine is ~~set up~~adapted for flameless oxidation of fuels. ~~For this purpose it~~This circulation flow has an internal space (9) in which a large-volume circulation flow is established. ~~This~~ To this end, the combustion chamber supplies a hot exhaust stream to the introduced air, the mass flow rate of which exceeds the fresh air stream. The fresh air and the fuel are fed to the combustion chamber in the same direction, roughly parallel to the wall.

~~(Figure 8)~~